

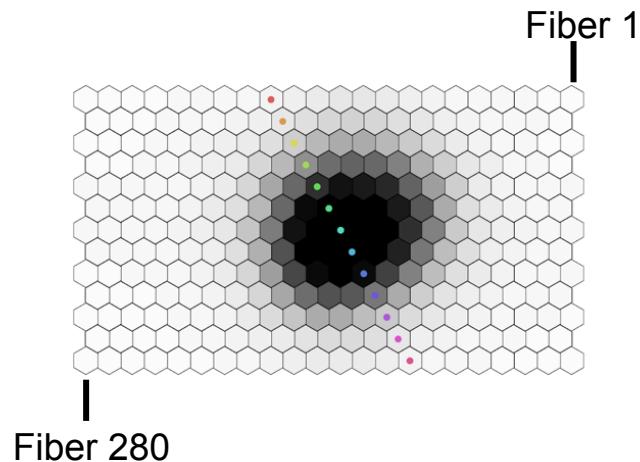
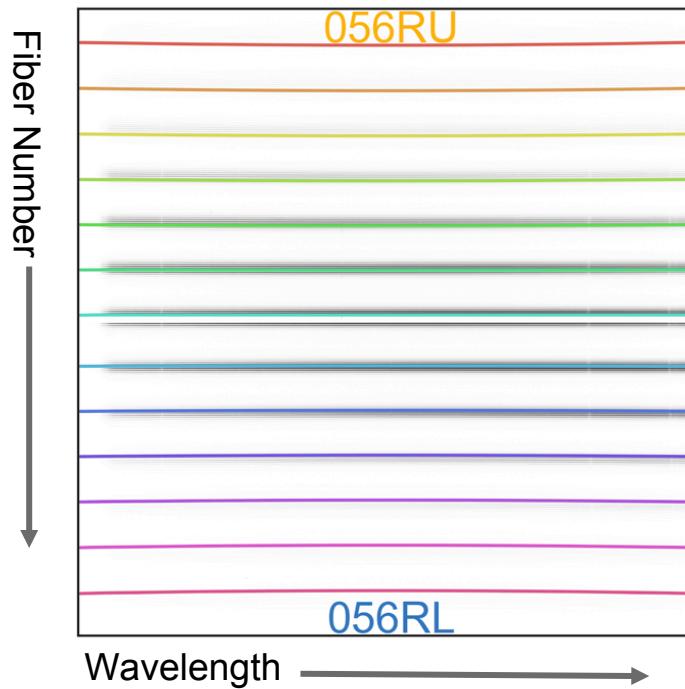
# LRS2 REDUCTIONS

Greg Zeimann  
**HET Data Scientist**

# Automatic Reductions

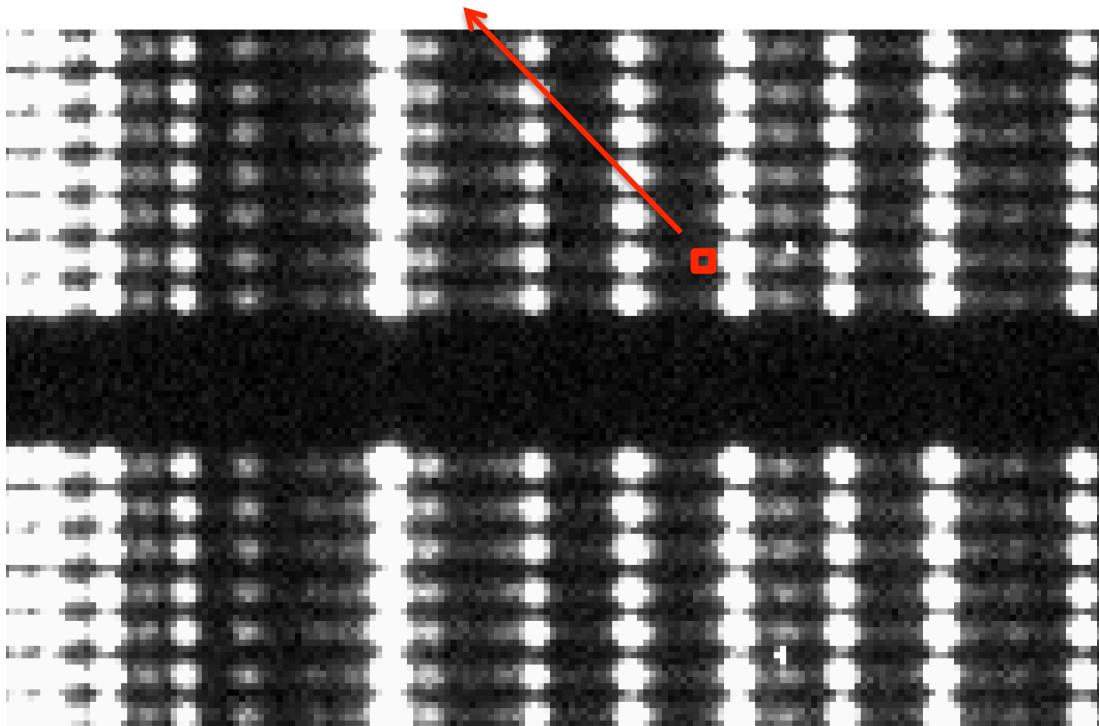
- Goal: Science-grade data reduction products
- Run from January 1<sup>st</sup> 2019 and on
- Older reductions can be run by the user
  - <https://github.com/grzeimann/Panacea#running-the-reductions-yourself>
  - Or email [grzeimann@gmail.com](mailto:grzeimann@gmail.com) for help
- TACC resources: Wrangler and Stampede2
- Pipeline reference in preparation (Zeimann et al. 2019)

# Mapping Raw Data to Sky



# Panacea: a python based reduction code

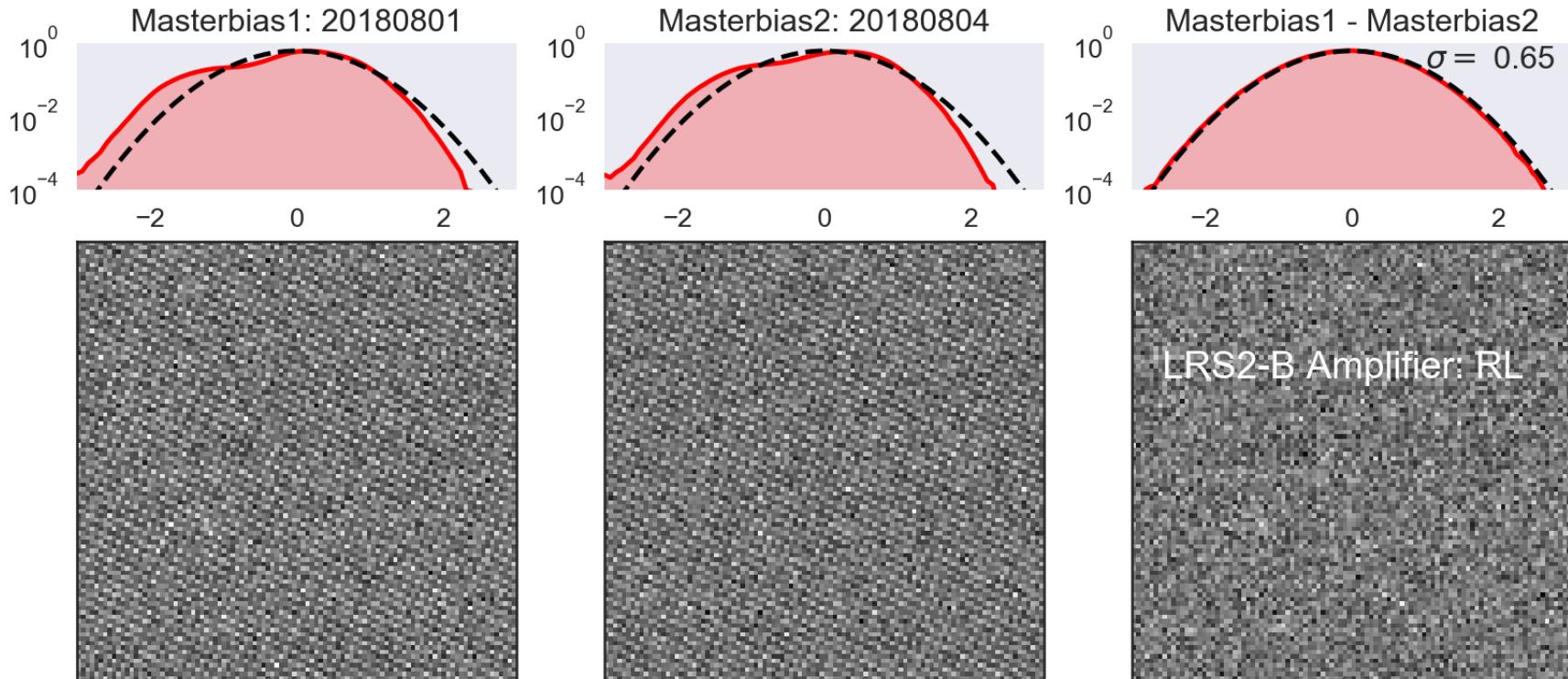
$$P_{ij} = B + B_{ij} + D_{ij} + Q_{ij} \times (S_{ij} + \text{Sky}_{ij} + \text{Sci}_{ij}) + \delta_{ij}$$



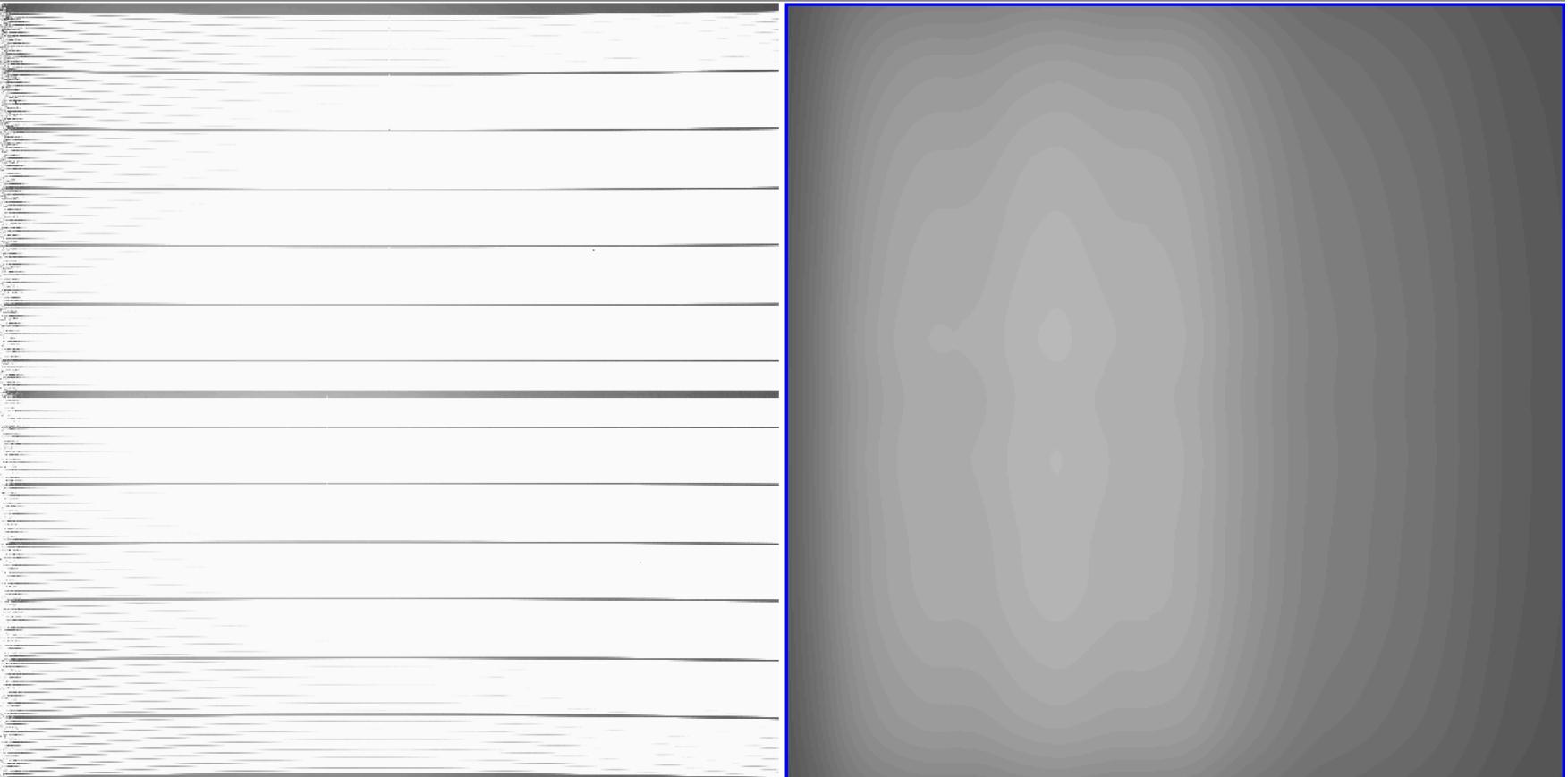
- B: Overscan
- $B_{ij}$ : Bias Structure
- $D_{ij}$ : Dark
- $Q_{ij}$ : Pixel to Pixel Variation
- $S_{ij}$ : Scatter Light
- $\text{Sky}_{ij}: \sum_{fw} \text{Sky}_f(w) \times \text{PSF}_f(w)$
- $\text{Sci}_{ij}: \sum_{fw} \text{Sci}_f(w) \times \text{PSF}_f(w)$

# Bias Subtraction: Master Bias Pattern (Evolves Slowly)

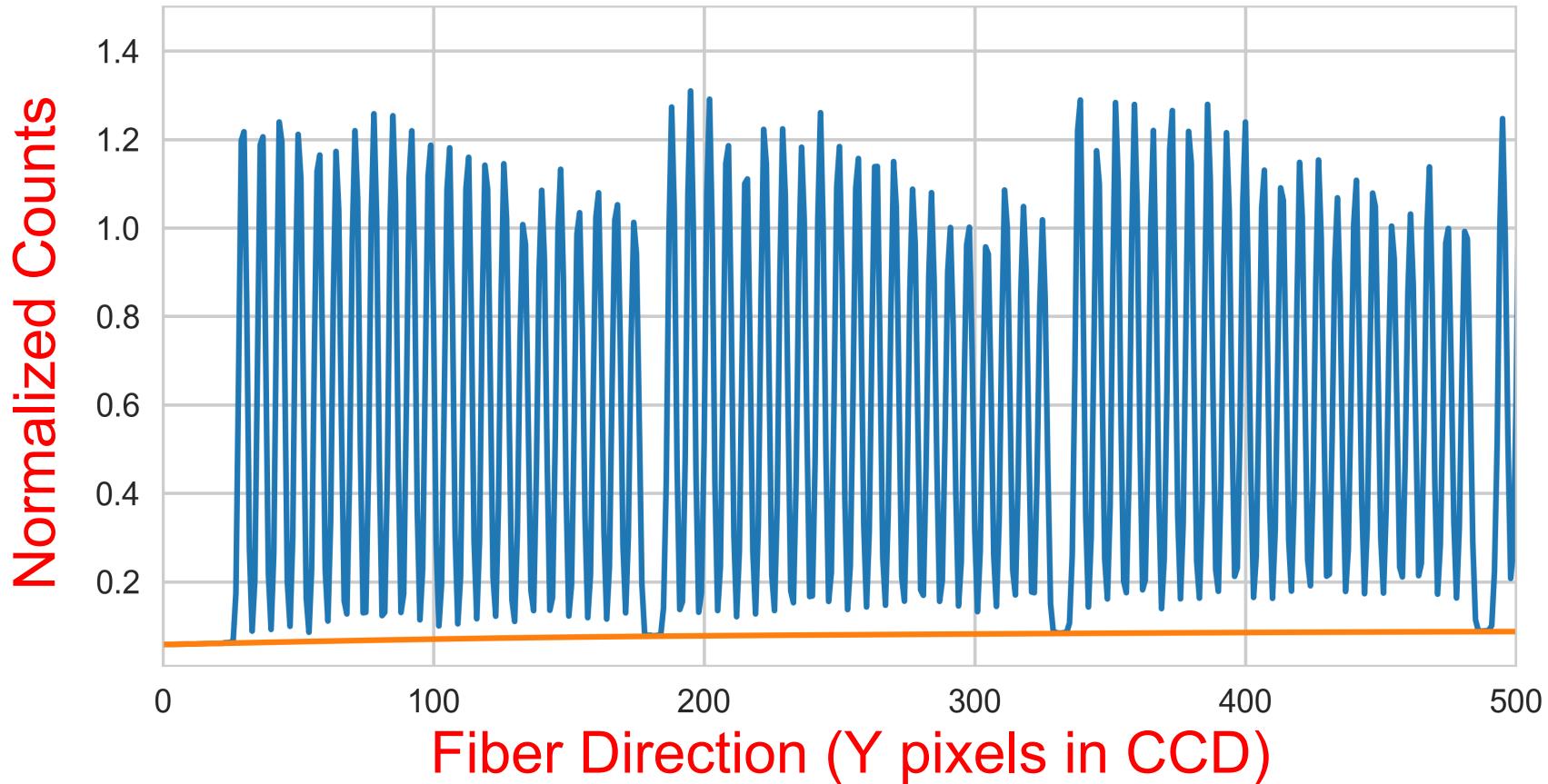
Initial Noise (Read Noise + Pattern Noise) =  $\sim 3.0$  e-



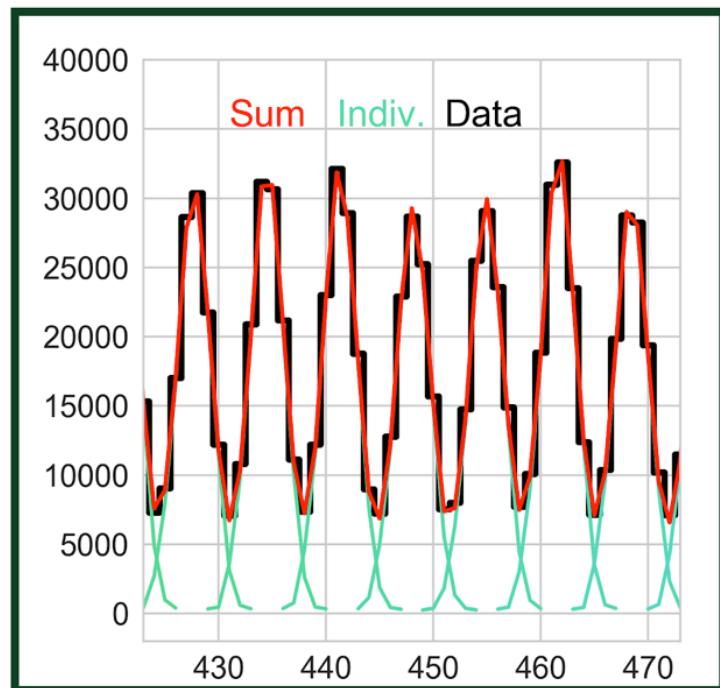
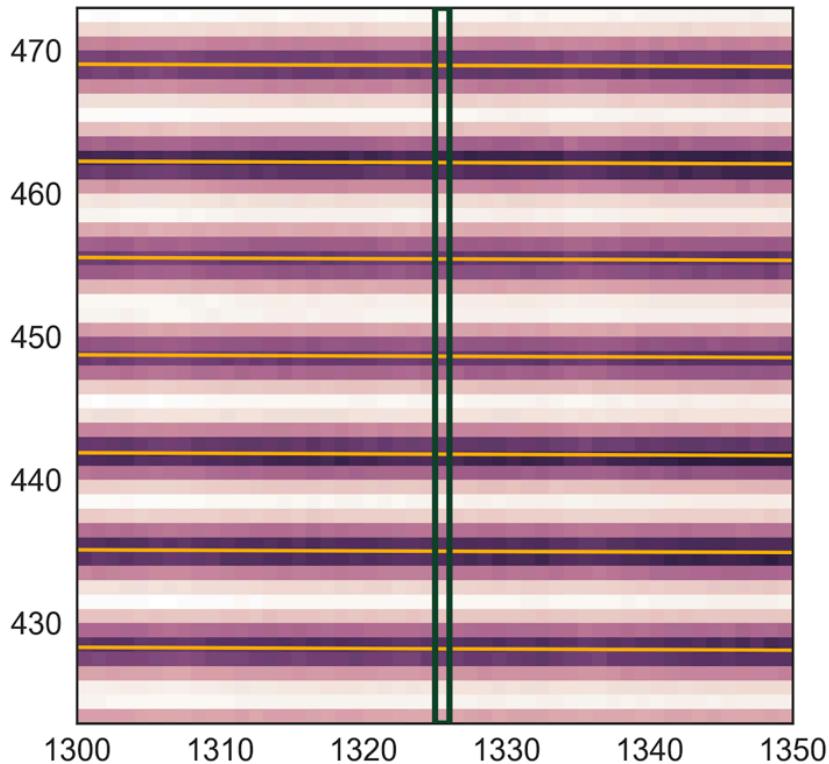
# Scattered Light: powerlaw



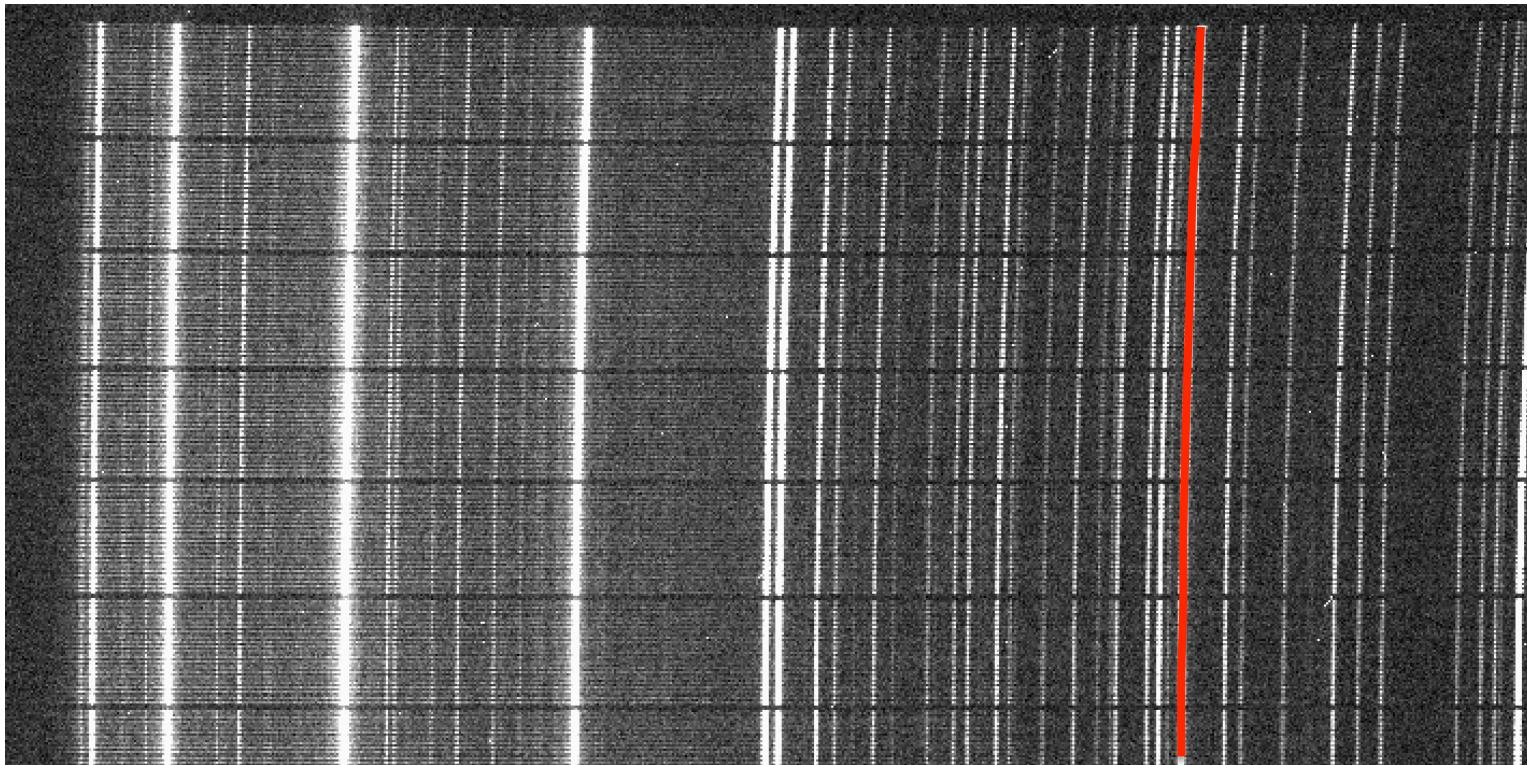
# Scattered Light: powerlaw



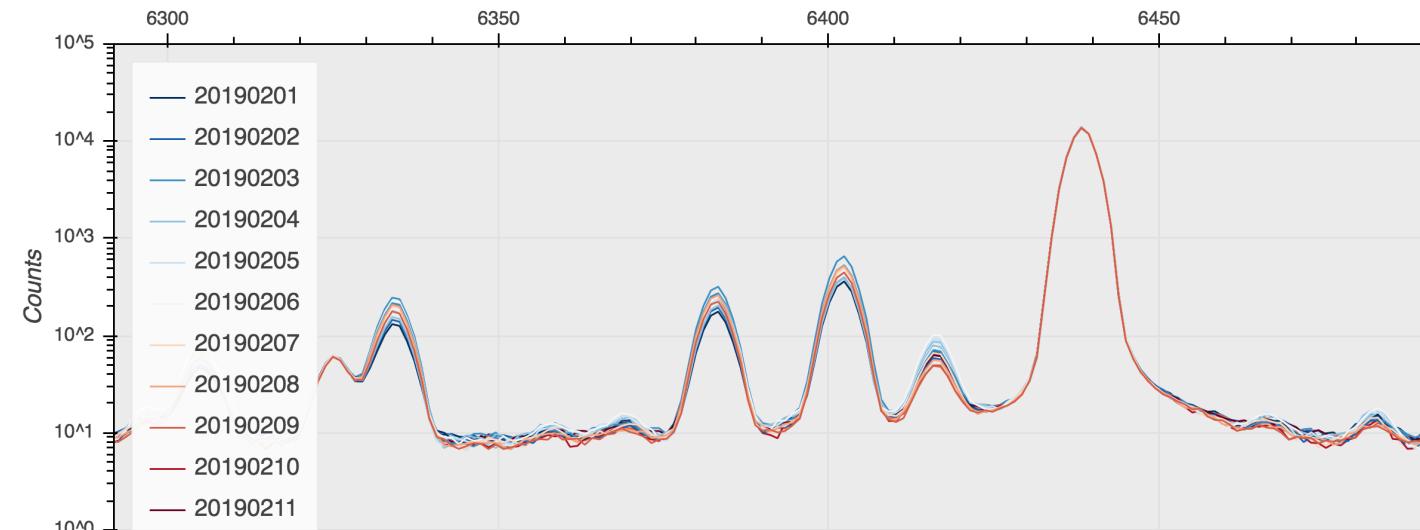
# Trace: peak estimation with quadratic



# Wavelength Solution: Hg, Cd, Ne, FeAr



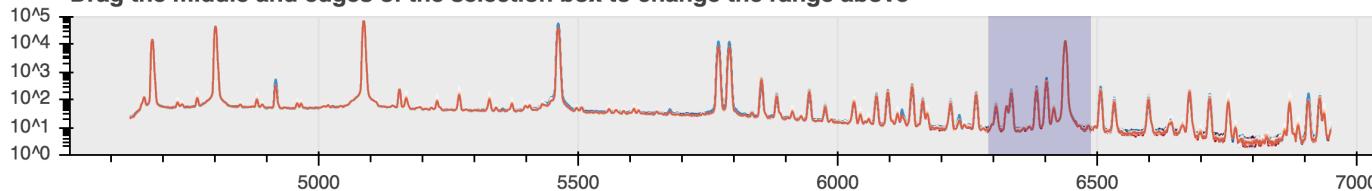
# Wavelength Solution: 3<sup>rd</sup> order Poly



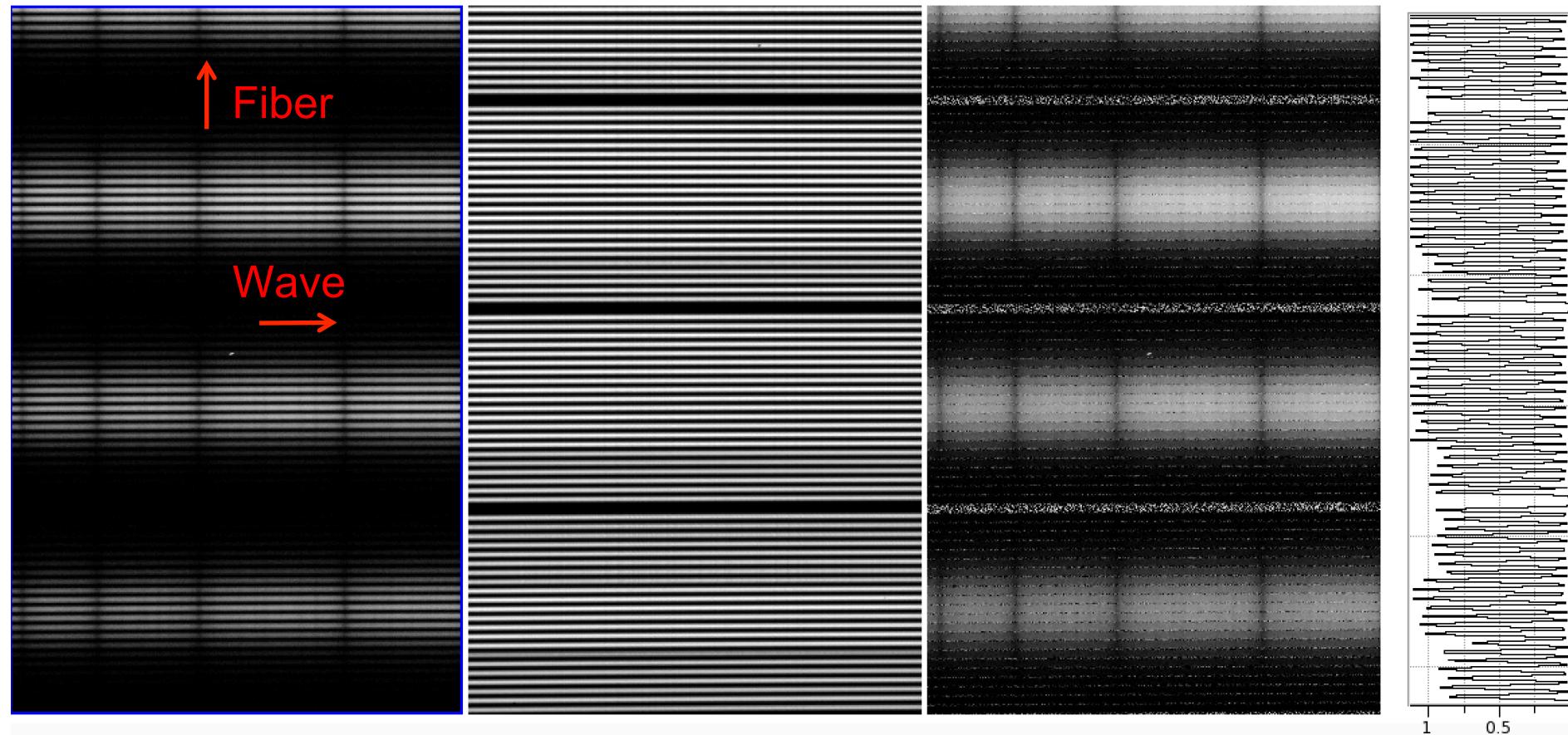
*Air wavelengths*

*No barycentric  
correction*

Drag the middle and edges of the selection box to change the range above



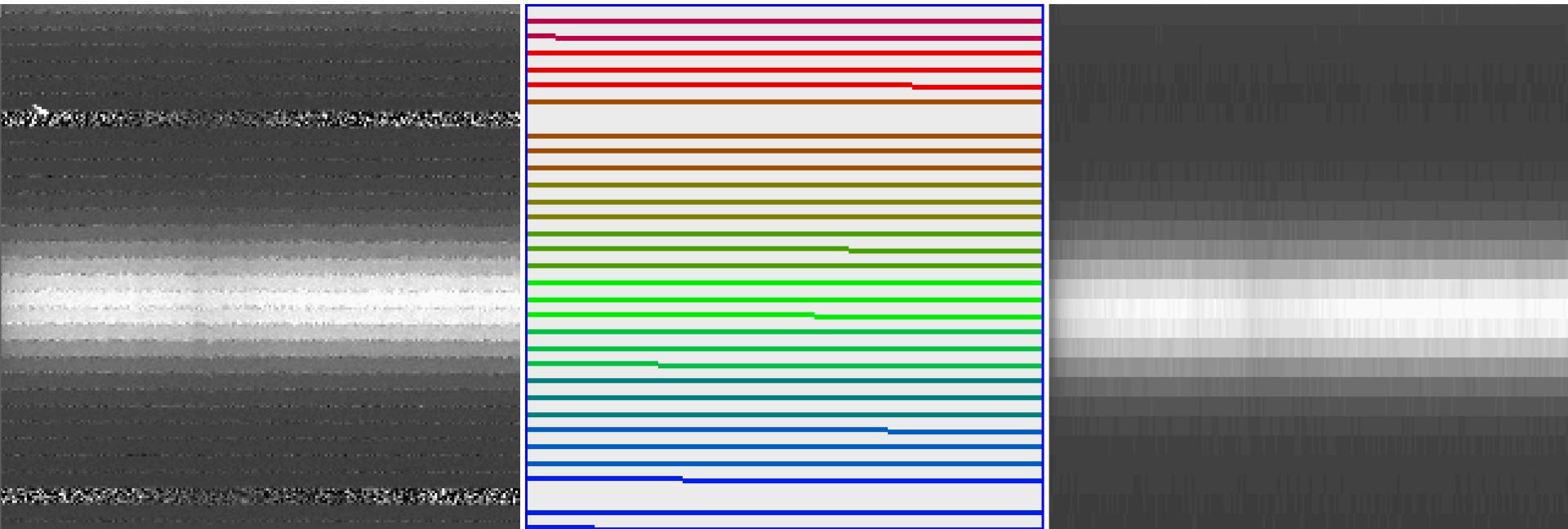
# Flat Fielding



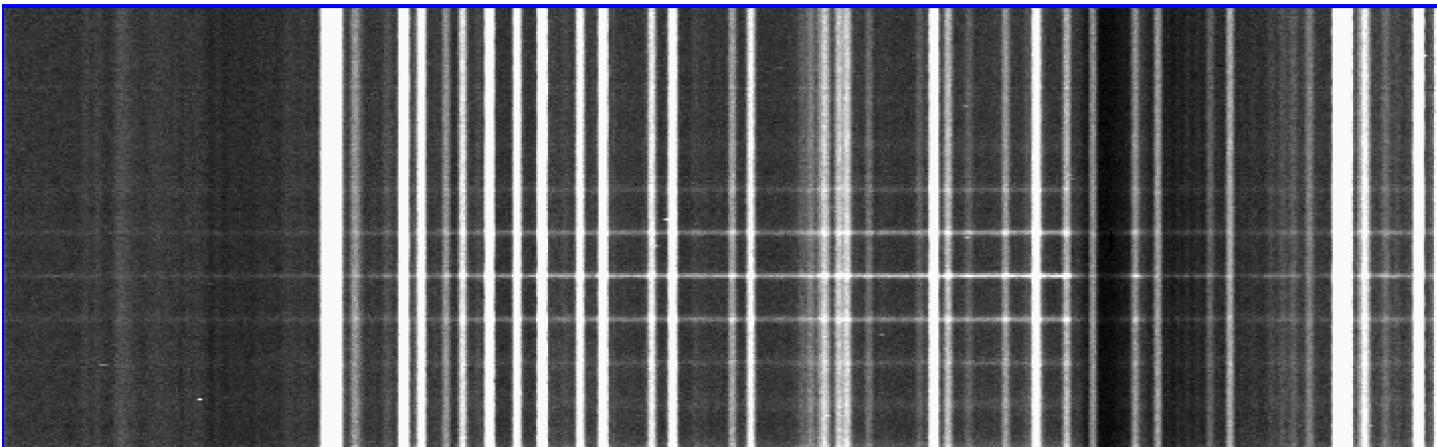
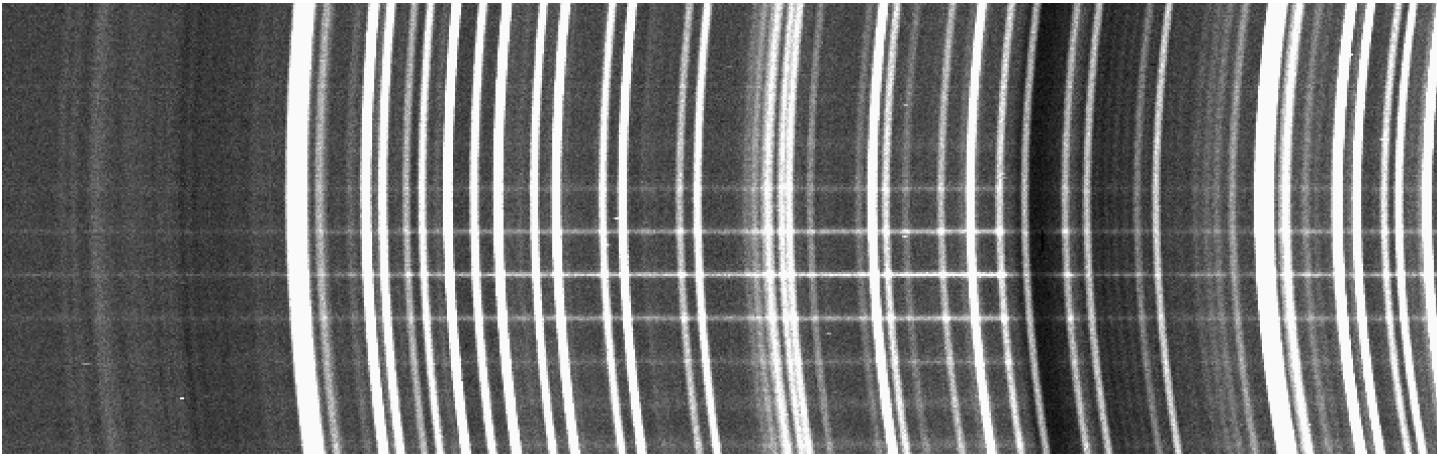
# Fiber Extraction

Row x Column → Fiber x Column

2064 x 2064 → 280 x 2064



# Linear Rectification



# Sky Subtraction

Step 1: Median of the bottom 5% fibers

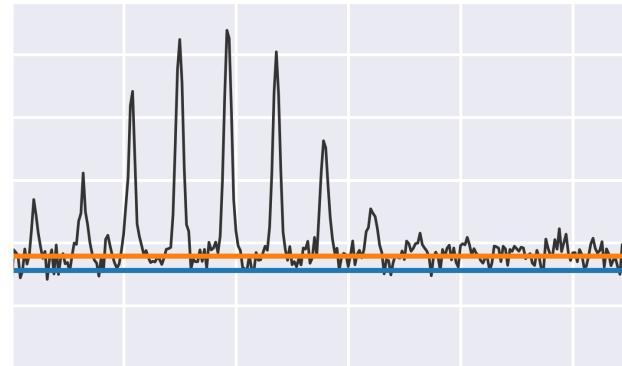
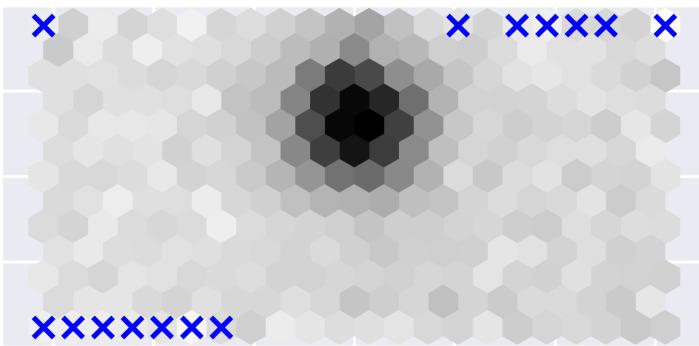
Step 2: Find scaling to sky lines for each fiber

Step 3: Subtract

Step 4: Keeping the same scaling per fiber fixed, subtract  
residual sky up to  $0.5\sigma$

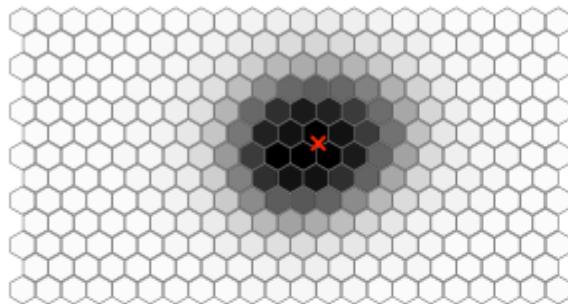
Caveat: Does not deal with differential spectral dispersion  
of each fiber

# Sky Subtraction

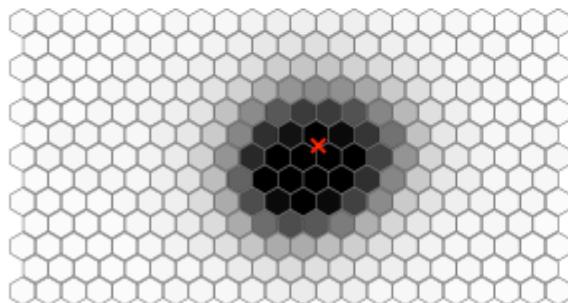


# Atmospheric Differential Refraction

ORANGE  
CHANNEL  
BLUE  $\lambda$

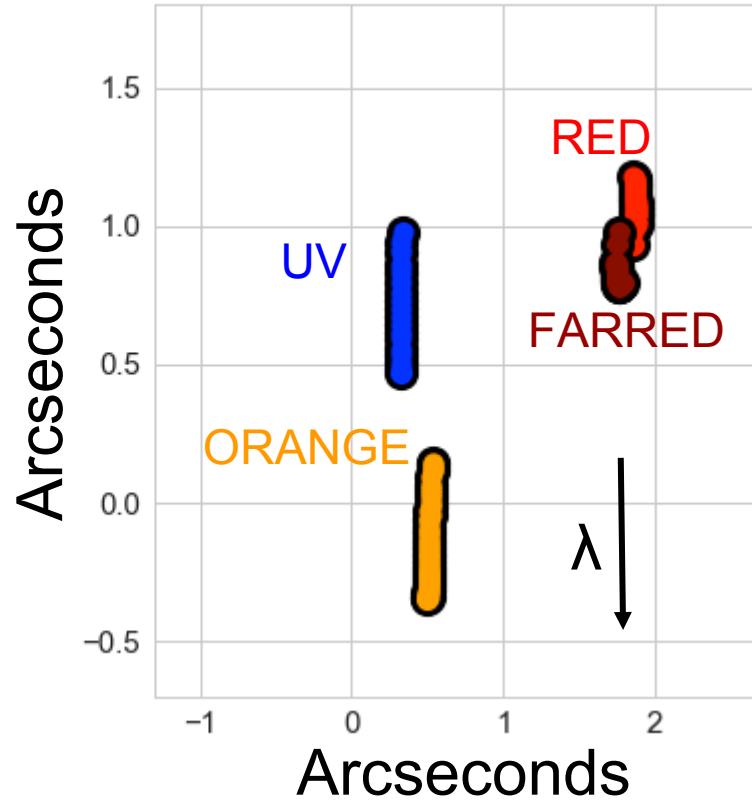


ORANGE  
CHANNEL  
RED  $\lambda$



4700 Å

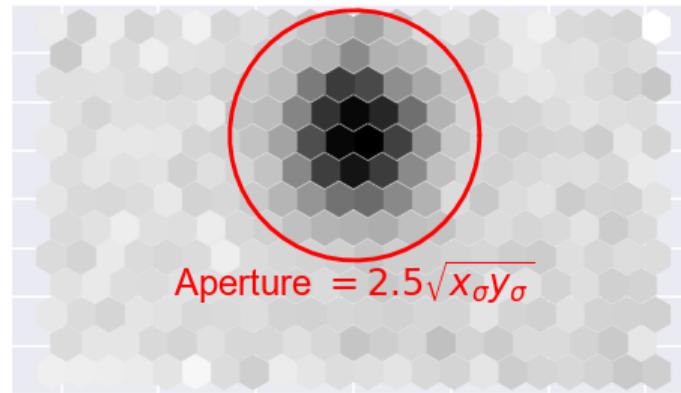
6700 Å



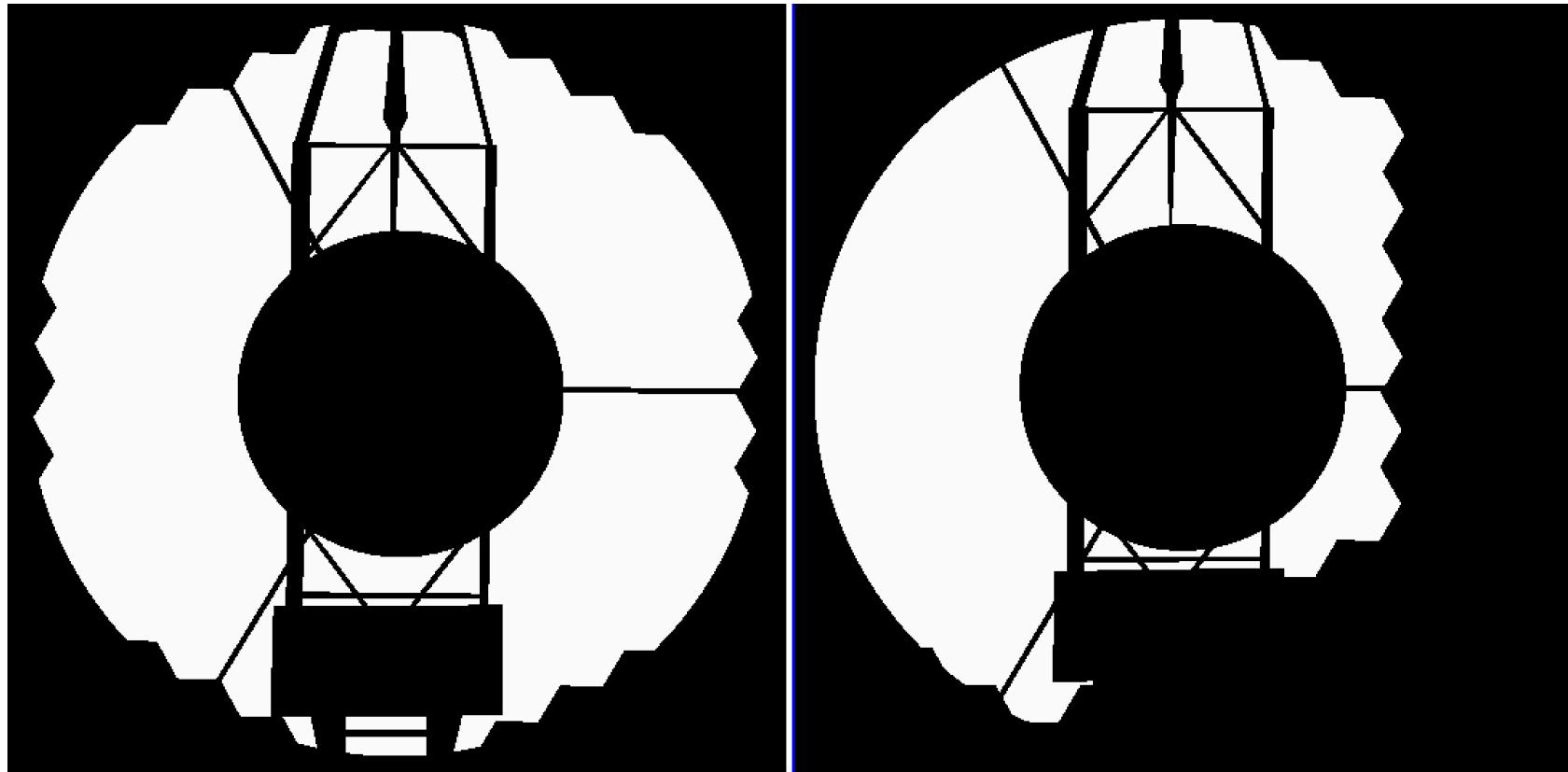
# Object Extraction (Emission and Cont.)

- ① Aggressively mask sky lines ( $|\lambda - \text{skyline}| < 6\text{\AA}$ )
- ② **Aggressively mask cosmics**
- ③ Convolve spatially ( $r = 0.75''$ )
- ④ Convolve spectrally ( $r = 1.5$  pixels)
- ⑤ **Locate maximum S/N in convolved cube**
- ⑥ Expand in wavelength direction if S/N increases
- ⑦ If S/N > 5, fit bivariate Gaussian to maximum S/N image
- ⑧ **Use bivariate Gaussian for weighting in optimal extraction**

# Object Extraction (Emission and Cont.)



# Flux Calibration (HET is complicated)



# Flux Calibration (HET is complicated)

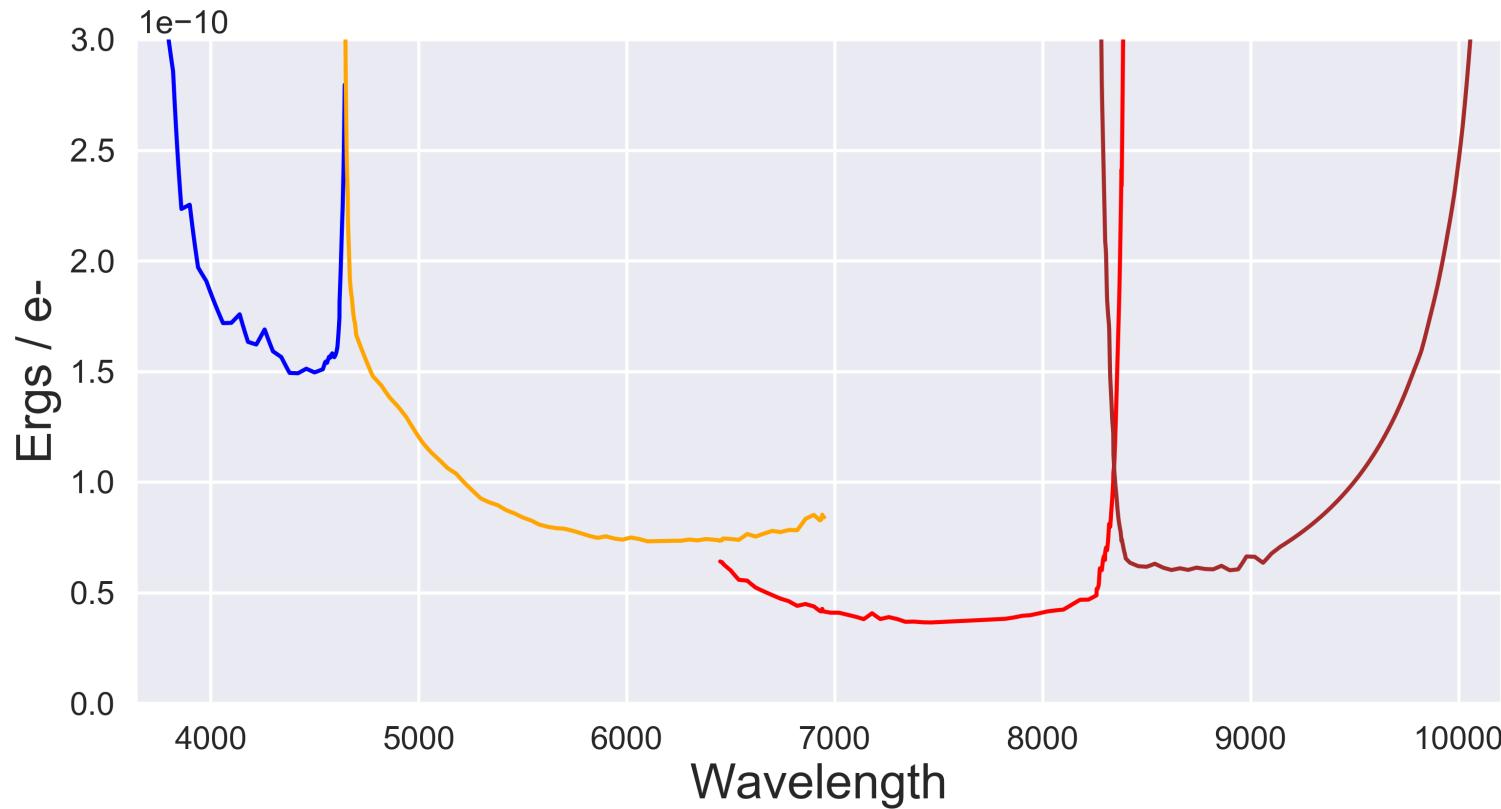
- ① Raw data: ADU per pixel
- ② Initial extracted fibers: e<sup>-</sup> / Å
- ③ Mirror illumination and exposure time: e<sup>-</sup> / s / cm<sup>2</sup> / Å
- ④ Single response function: ergs / s / cm<sup>2</sup> / Å
  - ① All fibers and spectra

Atmospheric extinction not included

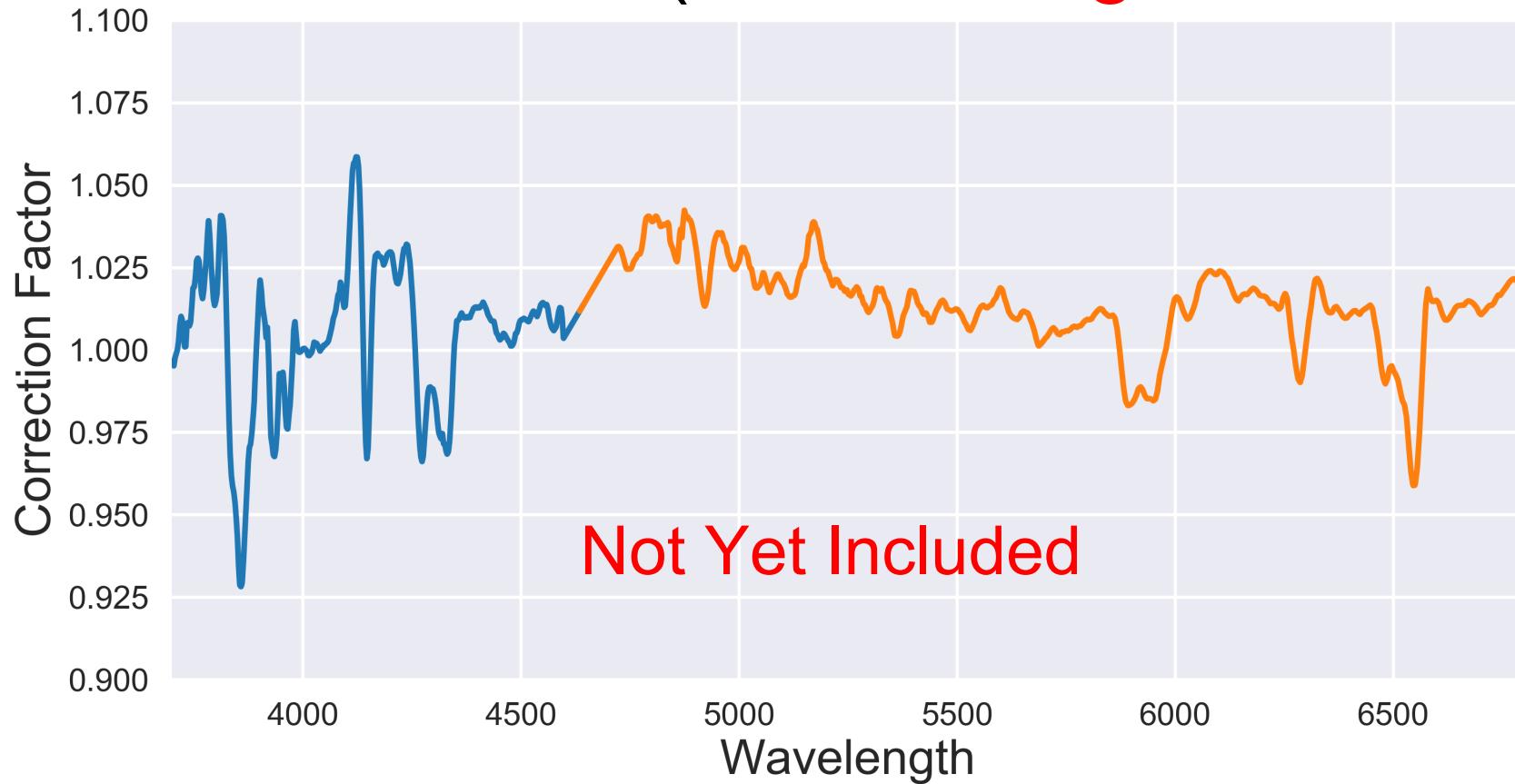
No telluric correction

Instrument assumed stable

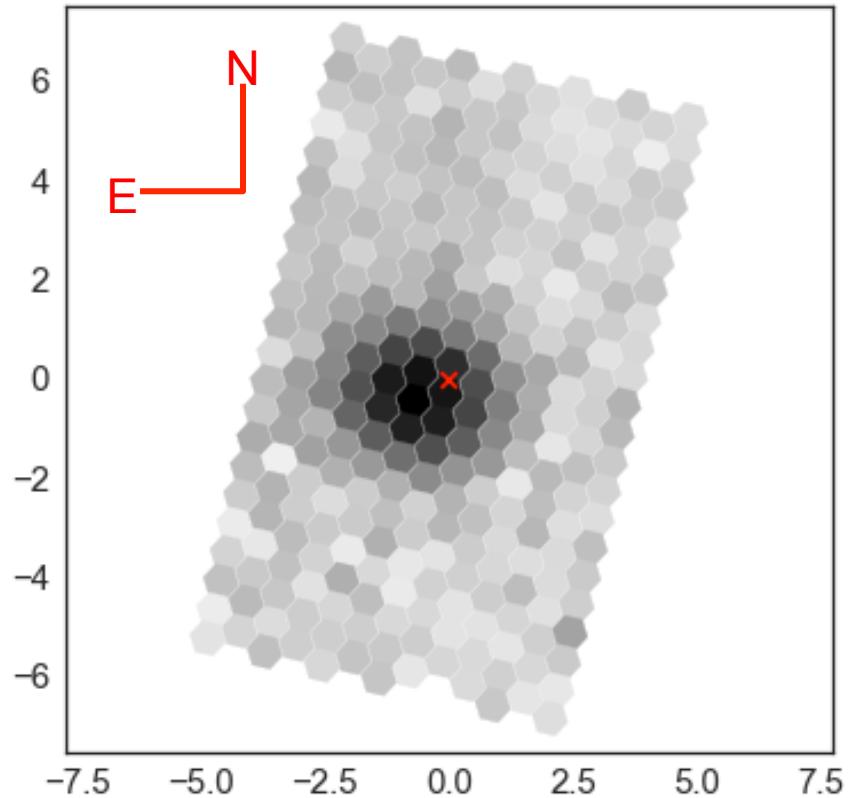
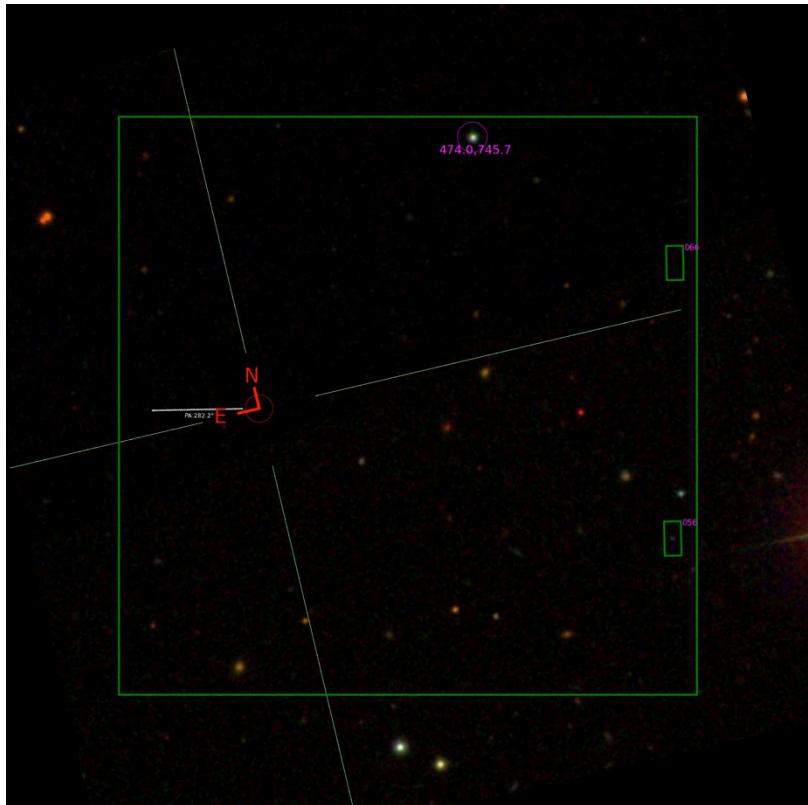
# Flux Calibration (One single response)



# Flux Calibration (Flat fielding correction)



# Astrometry



# Documentation: <https://github.com/grzeimann/Panacea>

← → C GitHub, Inc. [US] | https://github.com/grzeimann/Panacea ⌂ ⌃ ⌚

## Panacea v1.0 (Automatic LRS2 Pipeline)

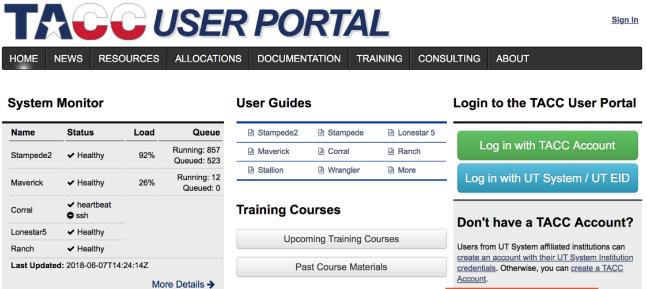
This package is the reduction pipeline for LRS2 observations at the Hobby Eberly Telescope. Every morning the pipeline reduces data taken the previous night. Below we discuss the algorithms and products of Panacea, how to access your data reductions, and how to run the pipeline yourself with varying options. All of the data reduction products live on the Texas Advanced Computing Center (TACC). We start with the instructions to log on to TACC, and where you reductions are placed.

### Working on TACC

The reductions are designed to be run on TACC where a copy of the raw data lives. We will describe how to get started on TACC, where the automatic reduction products live, how to run the code yourself, and the products that are produced.

#### Signing up for an account

<https://portal.tacc.utexas.edu/>



The screenshot shows the TACC User Portal homepage. At the top, there's a navigation bar with links for HOME, NEWS, RESOURCES, ALLOCATIONS, DOCUMENTATION, TRAINING, CONSULTING, and ABOUT. On the left, a "System Monitor" table lists resources: Stampede2 (Status: Healthy, Load: 92%, Queue: Running: 857, Queued: 523), Maverick (Status: Healthy, Load: 26%, Queue: Running: 12, Queued: 0), Corral (Status: heartbeat, ssh), Lonestar5 (Status: Healthy), Ranch (Status: Healthy). Below the monitor is a "Last Updated: 2018-06-07T14:24:14Z" timestamp and a "More Details" link. In the center, there are "User Guides" for Stampede2, Stampede, Lonestar 5, Maverick, Corral, Ranch, Station, Wrangler, and More. At the bottom, there are sections for "Training Courses" (Upcoming Training Courses, Past Course Materials) and "Don't have a TACC Account?" with links for "Log in with TACC Account" and "Log in with UT System / UT EID".

How to retrieve your reductions

Description of algorithms

Description of products

Frequently asked questions

# LRS2 Pipeline (Started Jan 1st)

Automated email example:

Your program got new data:

Object	File	Setup	Accept	RA_notes
OBJNAME_056_W	lrs20000024_01	LRS2-B	accepted	
OBJNAME_066_W	lrs20000025_01	LRS2-R	accepted	

Data reductions complete.

Your reductions can be found on TACC: /work/03946/hetdex/maverick/LRS2/HET19-1-999

Description of the reduced products, the pipeline, and how to access the data are here: <https://github.com/grzeimann/Panacea>

Please contact Greg Zeimann ([grzeimann@gmail.com](mailto:grzeimann@gmail.com)) if you have any questions about your reductions.

# How to get your reductions

Step 1: Get TACC account; email [shetrone@astro.as.utexas.edu](mailto:shetrone@astro.as.utexas.edu)

## TACC USER PORTAL

[Sign In](#)

[HOME](#) [NEWS](#) [RESOURCES](#) [ALLOCATIONS](#) [DOCUMENTATION](#) [TRAINING](#) [CONSULTING](#) [ABOUT](#)

### System Monitor

Name	Status	Load	Queue
Stampede2	✓ Healthy	92%	Running: 857 Queued: 523
Maverick	✓ Healthy	26%	Running: 12 Queued: 0
Corral	✓ heartbeat ✗ ssh		
Lonestar5	✓ Healthy		
Ranch	✓ Healthy		

Last Updated: 2018-06-07T14:24:14Z

[More Details ➔](#)

### User Guides

[Stampede2](#) [Stampede](#) [Lonestar 5](#)  
[Maverick](#) [Corral](#) [Ranch](#)  
[Stallion](#) [Wrangler](#) [More](#)

### Training Courses

[Upcoming Training Courses](#)  
[Past Course Materials](#)

### Login to the TACC User Portal

[Log in with TACC Account](#)  
[Log in with UT System / UT EID](#)

### Don't have a TACC Account?

Users from UT System affiliated institutions can [create an account with their UT System Institution credentials](#). Otherwise, you can [create a TACC Account](#).

[Create a TACC Account](#)



# How to get your reductions

Step 2: Copy your Program-ID to your convenient location

```
scp -r USER@wrangler.tacc.utexas.edu:/work/03946/hetdex/maverick/LRS2/PROGRAM-ID .
```

This will return four files for each exposure and each channel (e.g., Orange)

multi\_DATE\_OBSID\_expXX\_SIDE.fits

spectrum\_DATE\_OBSID\_expXX\_SIDE.fits

DATE\_OBSID\_expXX\_obs\_SIDE\_cube.fits

DATE\_OBSID\_expXX\_sky\_SIDE\_cube.fits

DATE\_OBSID\_expXX\_skysub\_SIDE\_cube.fits

# Reduction Folder Structure (on TACC)

Base = /work/03946/hetdex/maverick

## LRS2/CALS

Wavelength, trace, fiber flat image, arc spectra, master bias, ect.

## LRS2/STANDARDS

Standard stars for post flux calibration or telluric calibration

## LRS2/ORPHANS

Science observations without PROGRAM-ID's

## LRS2/PROGRAM-ID

Science observations belonging to PROGRAM-ID

# Data Reduction Products:

spectrum\_DATE\_OBSID\_expXX\_SIDE.fits

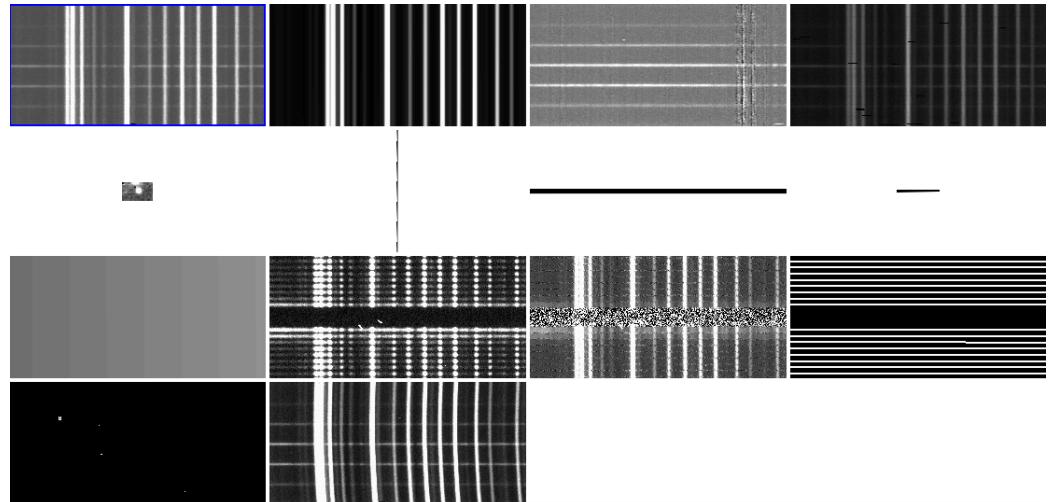
- 1) Wavelength
- 2)  $F_{\lambda}$  (ergs / s / cm<sup>2</sup> / Å)
- 3) Sky <sub>$\lambda$</sub>
- 4) e\_F <sub>$\lambda$</sub>
- 5) e\_Sky <sub>$\lambda$</sub>
- 6) Response

```
import matplotlib.pyplot
import glob
from astropy.io import fits
plt.figure(figsize=(10, 8))
fn = glob.glob('PROGRAM-ID/spectrum_DATE_OBSID_EXP_*.fits')
for f in fn:
    F = fits.open(f)
    plt.plot(F[0].data[0], F[0].data[1])
```

# Data Reduction Products:

## multi\_DATE\_OBSID\_expXX\_SIDE.fits

1. Rectified Spectra
2. Rectified Sky Model
3. Rectified Sky Subtracted Spectra
4. Rectified Error Frame
5. Collapsed image
6. Positions (IFU, Focal, Sky)
7. Extracted Spectra and Response
8. ADR
9. CCD Wavelength
10. Image
11. Flat Fielded image
12. Central Trace Pixels
13. Cosmics
14. Unrectified Spectra



# Data Reduction Products:

DATE\_OBSID\_expXX\_{kind}\_SIDE\_cube.fits

QFitsView

